TagAlong RolePlay:
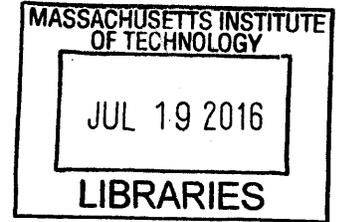## A Low-Cost Multi-User Virtual Reality Language Learning Platform

By Remy Mock

S.B. in EECS and Mathematics, MIT (2014)

Submitted to the Department of Electrical Engineering and Computer Science

in Partial Fulfillment of the Requirements for the Degree of

Master of Engineering in Electrical Engineering and Computer Science

at the

Massachusetts Institute of Technology

May 2016 [June 2016]

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Accepted by.

Dr. Christopher J. Terman Chairman, Department Committee on Graduate Theses

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TagAlong RolePlay:

A Low-Cost Multi-User Virtual Reality Language Learning Platform

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ABSTRACT
Smart-phone applications that help users learn languages are quickly taking over the language learning market due to their convenience and accessibility. It is estimated that the mobile share of the language-acquisition market should climb 73 percent to around 14.5 billion by 2019 (Reuters, 2015). However, none of the applications currently available are immersive or have multi-user features. Immersive learning and tandem learning has been shown to have many benefits. TagAlong RolePlay is a low cost multi-user VR platform that was created to incorporate this type of learning. Furthermore, TagAlong RolePlay has an authoring tool that allows teachers to create various virtual language-learning environments and tasks. This allows a teacher to create tasks specific to the student's needs. For example, a student trying to learn English to become a doctor in the US will need to learn the words pertaining to the medical world. The robust and flexible TagAlong RolePlay platform creates a more superior efficient and engaging learning experience.

Thesis Supervisor: Pattie Maes

Title: Professor of Media, Arts and Sciences

Acknowledgements

"You live a new life for every new language you speak. If you know only one language, you live only live once" – Czech Proverb

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Chapter 1: Overview

1.1 Introduction

Imagine for a moment you are trying to learn a second language. Instead of taking language class, you've decided to use a second language acquisition application on your smart-phone because they are inexpensive and can be done in the comfort of your own home. The first few days go very well. However, it is boring, repetitive and after a week you lose interest. Since consistency is crucial for language learning, the application keeps sending you notifications to not forget to complete today's exercise. However, you're not in the mood so you just ignore the notification and continue watching your favorite TV show on Netflix.

Imagine instead, when trying to learn Japanese you are fully immersed in a virtual Japanese grocery store. You can turn your head to look around and see all the different items on sale. In addition, your teachers and peers are in the environment with you and you are able to interact with them. Imagine being able to do all this with just your smart-phone and in the comforts of your own home. Furthermore, nothing needs to be installed on the phone, it is as simple as going to a website.

This thesis is about creating an engaging and effective multi-user platform to help smart-phone users learn a second language. The application incorporates peer learning, task-based learning, conversational-based learning and most importantly immersive learning where learning takes place in an immersive virtual environment.

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1.2 Thesis Outline

The thesis is organized as follows: Chapter 2 focuses on the background knowledge of language learning, specifically in the topic of technology assisted language learning. Several language technologies created by others are reviewed. In Chapter 3, the *TagAlong RolePlay*, the browser-based multi-user Virtual Reality language-learning platform and its features which are derived for the background knowledge of language learning are discussed and the mechanics of VR is explained. Adding on to Chapter 3, Chapter 4 discusses the details of the implementations of the *TagAlong RolePlay* platform. This chapter will cover the design behind the scene rendering, peer-to-peer communication, Speech Recognition, Text-to Speech and so-forth. *SceneCreator,* the authoring tool for teachers is discussed in Chapter 5. Other applications of the *TagAlong RolePlay* platform are discussed in Chapter 6, specifically using *TagAlong RolePlay* for campus/museum tours and for STEM learning. Lastly in Chapter 7, a conclusion and ideas for future work is given.

Chapter 2: Literature Review

The goal of *TagAlong RolePlay* is to make an efficient and optimal language learning platform. To accomplish this task, it is important to understand the theories behind language acquisition. This way, we only add features to the platform, that are most effective to language learning. In this chapter, we will cover multiples theories and fields of language learning such as peer learning, tandem learning, and flow theory. We will also see what technological based learning applications exists in the market and to see how *TagAlong RolePlay* can improve upon them.

2.1 Theories

There are many types of language learning, each bringing their own advantages to the table. In this section they will be discussed.

2.1.1 Peer Learning (collaborative learning)

There are many benefits of having the application be a one that is multi-user. One of them is the concept of peer learning, which is an educational practice in which students interact with their peers to acquire educational goals (O'Donnell, 1999). Peer learning

gives the user opportunity to learn via constructive criticism and feedback from teachers and their peers. Furthermore, it makes learning a language more engaging, and a more motivating due to positive peer pressure. This collaboration created an environment that is sociable and adaptabile for language learners (Pan et al., 2007). Additionally, it increases interest among learners and promotes critical thinking which are the major benefits of collaborative learning (Dimitropoulos et al., 2008).

2.1.2 Tandem Language Learning

Tandem language learning is a method of language learning based on mutual language exchange between language partners. Ideally each learner is a native speaker in the language the proponent wants to learn. For example, a native German speaker wanting to learn Spanish will be pairs with a native Spanish speaker wanting to learn German. *LiveMocha* is an example to an online tandem language learning platform that is currently out there. Another older example is pen pals, where two people write emails or post mails to each other to learn a language. Tandem learning is ideal for motivated language learners who can't afford to pay for a language teacher. Instead, Tandem language learners do not need to pay anything since they are just exchanging knowledge. Furthermore, tandem learning develops intercultural competence (Belz, 2005) and is a very authentic experience which increases student motivation.

2.1.3 Immersive Language Learning

At one time or another, any individual serious in mastering a language will partake in an exchange program to be in an environment where that language is spoken. It is quite evident that immersive learning is a crucial part of second language acquisitions. Furthermore, it opens the door to other cultures and helps understand and appreciate people from other countries (Plass, 1996). However, partaking in an exchange program can be expensive and inconvenient.

2.1.4 Silent Way

The Silent Way is a discovery learning approach, invented by Caleb Gattegno in the late 1950s. (Gattegno, 1963). The teacher is mostly silent, giving more autonomy and space for the students to explore the language. Students are responsible for their own learning and are encouraged to express themselves. Beginners can talk about what they see, where as more advanced students talk about more complex topics such as their lives and their opinions. The role of the language teacher is not to model the language but to correct mistakes by giving sensible feedback.

2.1.5 Blended Learning

Blended learning is a form of education in which a student learns at least in part through delivery of content and instruction via digital and online media with some element of student control over time, place, path, or pace. (Knewton, 2011). While students still attend "brick-and-mortar" schools, face-to-face classroom methods are combined with computer-mediated activities. (Merrow, 2012). Blended learning is also used in professional development and training settings (Lothridge, Blended learning: efficient, timely, and cost effective, 2013). Blended instruction is reportedly more effective than purely face-to-face or purely online classes. (Jessica K. Beaver, 2014). Blended learning methods can also result in high levels of student achievement more effective than face-to-face learning (Guia, 2015).

2.1.6. Personalized Learning

Two students can be trying to learn English but for entirely different reasons. One may be trying to practice medicine and work in a hospital in an English-speaking country whereas the other might be trying to be an automobile mechanic in Canada. Although these two speakers are trying to learn the same language, one needs to learn

vocabulary pertaining to the medical world such as "syringe" and "bandage" where as

the other needs to learn worlds pertaining to the automobile world such as "tire" and

"engine". Most language learning platforms don't differentiate the language learning

process for people that need it for different contexts and purposes (except for business

language classes).

Personalized learning is a form of educational instruction that

uses learning environments to meet the individual student's needs. (Pogorskiy, 2015).

The experience is optimized to the learning preferences and the specific interests of

different learners. By tailoring the experience differently for each user, their engagement

can be maximized.

2.1.7 Realistic/Situated Learning

Situated Learning is a learning practice in which the student learns a skill in the same

realistic manner that it is applied. Piaget and Dewey believed that the language

teacher's role was to shape a students' real experience and to understand and create

the environments that tend to encourage positive learning experiences (Ornstein, 1998).

Dewey believed that students should learn in a real situation by doing, so students

could improve their skills through practice on realistic tasks (Dewey, 1916).

"Constructivists emphasize the design of learning environments rather than instructional

sequences". The learning environment should provide real world, case-based environments for meaningful and authentic knowledge". (Jonassen, 1994)

An example of a language learning platform that uses situated learning is *Voxy*. *Voxy* is a mobile application that delivers content based on your personal interests. You learn new vocabulary from the latest headlines on a topic of your choice. *Voxy* also has features that deliver related vocabulary based on your location, such as a grocery store or hospital.

2.1.8 Flow Theory

Originated by Mihaly Csikszentmihalyi in 1975, Flow Theory has been studied in depth for the last 35 years in many various aspects. (Csikszentmihalyi, 1975). The concept of flow theory is that learners perform best when their skill set and the difficulty of the task being completed are in balance. When a student's skill level is too high for a given task, they become apathetic or bored, and if the difficulty of the task is too high for their ability level, they may become worried or anxious. In contrast, when skill and challenge are balanced, they are in a flow channel and are in a state of flow. In order to achieve flow, the activity must challenge and require skill, merge action and awareness, provide feedback, and require full concentration on the task at hand (Finneran, 2002). Flow leads to self-motivation and enjoyment, and the learner's skills improve at the faster

pace. When people are in the flow state, they often become in the zone, lose track of time and forget to realize that learning is taking place. Studies by Egbert, found that flow can occur in a foreign language classroom. (Egbert, 2003) Egbert claims Flow depends on a variety of factors, such as a deep sense of enjoyment and playfulness. There many factors that affect flow such as the individual's characteristics, as well as conditions and tasks in the learning environment. Other learners in the environment can also affect a user's flow. Additionally, flow relates to focused attention on a given task, interest in the task, and control over the task (Egbert, pp. 559-561). Flow theory stipulates that individuals will generally repeat an activity if they like it. This means individuals will be likely to continue learning and reach their goal of achieving fluency.
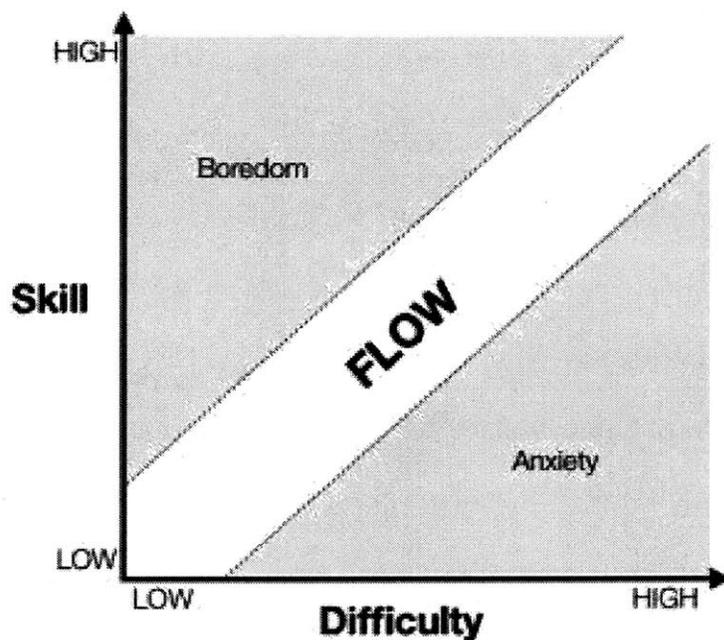
Figure 1 Flow Theory

2.1.9 Edutainment Learning

"Learning through play" or the genre of computer games involved with education is called "edutainment"" (Kowit Rapeepisarn, 2006). In Taiwan and Japan, memorization of grammar and vocabulary is the primary method for teaching English as a foreign language. This results in low student motivation and provides an environment where students question their level of confidence and feel that their ability to learn English is challenged. Hwa Hsu and et.al. (Hwa Hsu S., 2008) found that there could be a remarkable change in student's capability if the learning process is enjoyable. Therefore, including entertaining activities like computer games, movies and online interaction as part of the classroom instruction can result in a more effective learning experience especially for adult English language learners. This is especially true for children and younger learners. Combining computer games into learning could be an appropriate way to motivate their learning.

2.2 Virtual Environment Language Learning Platforms

Although a lot of research has gone into computer-mediated virtual environment language learning platforms, language learning using these platforms have not become widespread. A possible reasoning for this is that many foreign language teachers are afraid of losing control of the classroom by placing their students in a potentially chaotic virtual environment in which they learn language skills that are less than ideal (Wilkerson 2010). Due to such fears, language learning in virtual environments is an underexploited but potentially very powerful tool in language learning. Despite the fears, recently, foreign language learning using virtual platforms has begun to spread.

One of the main benefits of learning languages in a Virtual Environment is that it incorporates immersion, interaction, and imagination, which makes leaning an engaging process for the student (Zhenbo Li, 2009).

2.2.1 MOOs (multi-user, object-oriented domains)

MOOs are programs that allows users to interact with others in real-time while being surrounded by textual descriptions of objects and artifacts in the environment. (Kötter, 2003). *Dungeons and Dragons* is the most well-known MMO. What truly defines the MOO is its social aspect, or the ability for players within the MOO to interact with one

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another. (Turbee, 1999). Learners can ask each other about the meaning of an unknown word or phrase, anywhere in the world and communicate in real time, forming powerful relationships both with the environment and with each other. One of the reasons MOOs have been so successful in educational settings, particularly for foreign language learning, is their informal nature. The informality of it all helps to break down some of the anxieties that learners have, especially with regard to foreign languages. (Wilkerson, 2010) Users become self-conscious about pronunciation, and grammar, and so on, so being behind the screen, having the sort of veil of anonymity reduces anxiety and helps users focus on the language learning aspect. (Holmevik, 2000).

2.2.2 MMORPGs (Massive Multi-Player Online Role Playing Games)

The last kind of electronic-based language learning platforms that exist are called MMORPGs. Games such as *Second Life, World of WarCraft* or *Runescape* were not created on any pedagogical language learning basis. However, since these games are global and attract players from all over the world who speak different languages, they create a simulated environment of language immersion where students are given the opportunity to apply their language skills toward real life goals within an extensive context (Bryant, 2006).

2.3 Summary

After studying the pedagogical theories of language learning, exploring the many types of language learning, and seeing what already exists in the market in term of electronic language learning platforms, the features of *TagAlong RolePlay* were chosen carefully.

Taking everything in mind, TagAlong RolePlay was made to be in Virtual Reality to take advantage of immersive benefits of language learning. It was also made multi-user to take advantage of peer and tandem learning. Furthermore, it was made with tasks, to incorporate task-based learning. Lastly, an authoring tool called *SceneCreation* was added to allow teachers to create scenes and tasks. Being able to personalize learning experience takes advantage of autonomous learning and flow theory.

Chapter 3: *TagAlong RolePlay* Features

In Chapter 2, the many types of language learning were discussed. *TagAlong RolePlay* tries to take into account the topics discussed in the previous chapter to make a platform that incorporates all of them. The *TagAlong RolePlay* platform is tailored for use by multiple students, sharing a virtual environment using a google cardboard, while the teacher uses a tablet or computer to author the environment and guide the learning experience. The many features of *TagAlong RolePlay* will be discussed in this chapter.

3.1 Immersion in a Virtual Environment

The importance of immersive learning was discussed in section 2.1. *TagAlong RolePlay* was created to have students learn languages while immersed in a virtual environment. Furthermore, virtual environments offer more autonomy to the students which makes the learning experience more personal.

The virtual environment consists of multiple 360-degree pictures called photospheres that students can hop between. Students can view the environment on their smartphone in two modes: either in 2-D stereoscopic virtual reality or in monoscopic mode. Teachers can view the environment and their student's view using a tablet or desktop computer.

3.1.1 Virtual Reality (2-D stereoscopic)

The mechanics of Virtual Reality

Virtual Reality is a computer technology that simulates a user's physical presence in an environment, real or imagined, by wearing a head mount display. Virtual realities can increase the user's presence in the environment by using head tracking, locations based sounds, haptic feedback and so forth.

Virtual Reality has been around for quite some time. In 1968, Ivan Sutherland, created what is widely considered to be the first virtual reality system. (SUTHERLAND, 1968) However, due to the lack of sufficient technology back then, Virtual Reality did not gain the popularity to the masses. Thankfully, due to the rapidly progress of technology, Virtual Reality is increasing in popularity and shows much promise. As smartphones increase each year in resolution, high quality Virtual Reality becomes more accessible to consumers.

Figure 2 The phone display during 2-D stereoscopic mode

Google Cardboard

Google Cardboard is a VR system that uses a smartphone to create a virtual reality experience. *TagAlong RolePlay* uses Google Cardboard as the Virtual Reality headset to go with the smartphone.

3.1.2 Monoscopic Option

The *TagAlong RolePlay* Platform also offers a monoscopic mode for students who don't have a VR headset or for students who don't enjoy the VR experience for reasons such as VR sickness. Virtual reality sickness also known as cyber-sickness occurs when exposure to a virtual environment causes symptoms that are similar to motion

sickness symptoms. (LaViola, 2000) . The most common symptoms are general discomfort, headache, nausea, vomiting, sweating, fatigue, drowsiness, disorientation, and apathy. VR sickness is most prevalent for adults as more recent research has suggested that adults over the age of 50 are more susceptible than younger adults to virtual reality sickness. (Brooks, et al., 2010) . The user can click the goggle button on the screen to toggle back and forth between the Stereoscopic VR mode and monoscopic mode.

Monoscopic mode is also favorable for users with phones that have inaccurate accelerometers. The inaccuracies can lead to high amounts of drift which can make it hard to participate in the *TagAlong RolePlay* sessions. Furthermore, drift results in sensory conflict which oftentimes leads to virtual reality sickness. Users using the monoscopic mode can move pan around the scene by swiping, instead of turning their phones like in VR. This can be beneficial for users that are physically disabled with limited range of motion. Lastly, Monoscopic mode is ideal when the student is accessing the platform from a tablet. Although the Monoscopic has many advantages, it is also less engaging and immersive. It is up to the student to decide if stereoscopic or monoscopic mode is optimal for their learning experience.
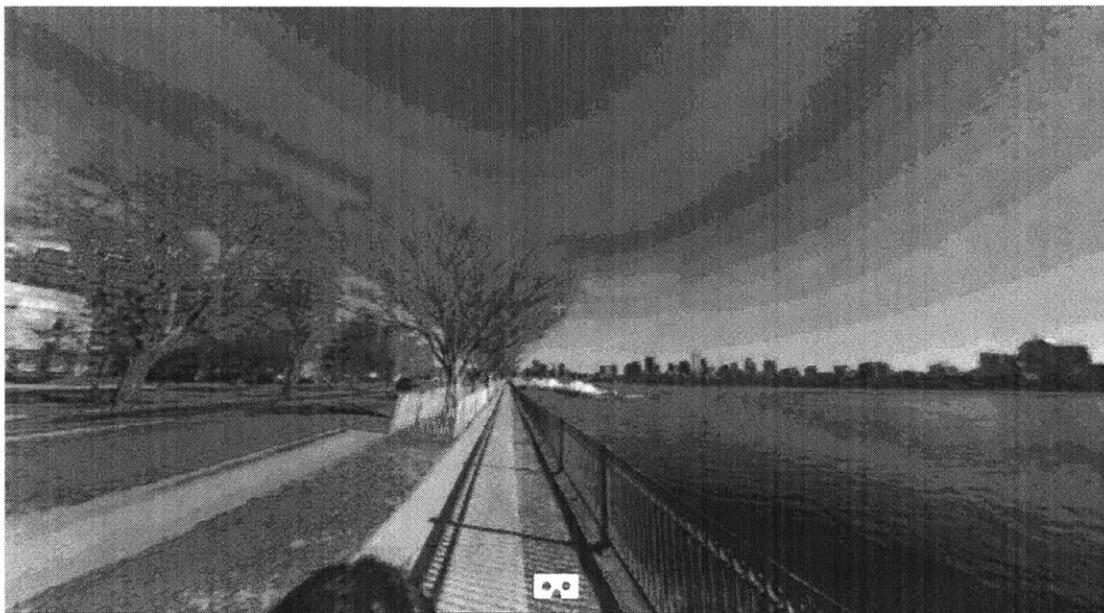
Figure 3 The phone display during monoscopic mode

3.2 Markers

Users can place markers in the virtual environment. The marker feature exists to aid users communicate and most importantly to help the teacher communicate with the students. Placing markers is analogous to the act of pointing in real life. Markers can also be used in tasks that require the student to find and place a marker on a given object. Each user has their own unique color so that the markers of the teacher and each student are differentiable. The markers are outline by a white ring are so that they are easily visible regardless of the background.

Figure 4 Markers placed in the virtual environment to aid in the interaction

3.3 Multi-User

To allow for peer and tandem learning, *TagAlong RolePlay* is multi-user. Multiple

Students can be in the same virtual environment together. Students are able to interact

with each other, have authentic conversations, perform tasks together and even

compete against each other with games.

3.3.1 Avatars

When a student is in the virtual environment their peers, they are displayed as avatars. The avatar consists of a square outline with the user's name on the top of the square and their profile photo on the upper right of the square. The square's location corresponds to where that peer is facing. The color of the square corresponds to the color of the marker of that peer. If a user doesn't fill out his name and picture when logging in, he is given a default avatar as shown below.
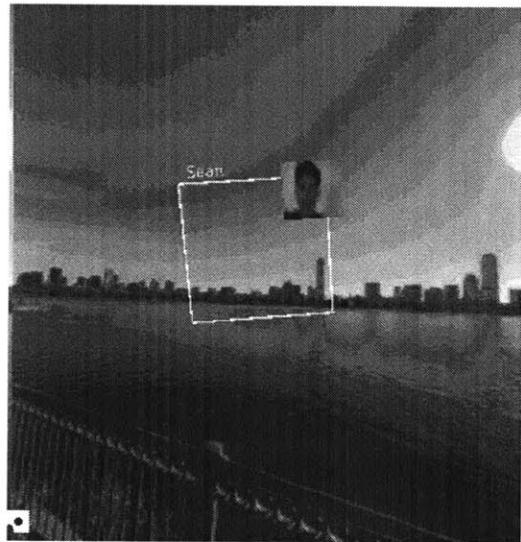
Figure 5 Avatar in student's view. Default (left), Filled in (right)

When the avatar is out of sight of the user's field of view, an arrow (with a peer's color) will appear facing the direction of the peer's whereabouts.

Figure 6 An Arrow showing the location of other students

3.4 Dialogue feature

The dialogue feature is another great tool in the *TagAlong RolePlay* platform to enhance the language learning process. In the virtual environment, users can speak to virtual characters with pre-scripted virtual characters. For each remark or question the virtual characters has, the user can decide between a collection of responses, in which the virtual characters will reply appropriately. The virtual character's response will be audible using the phone's Text-to-Speech feature.
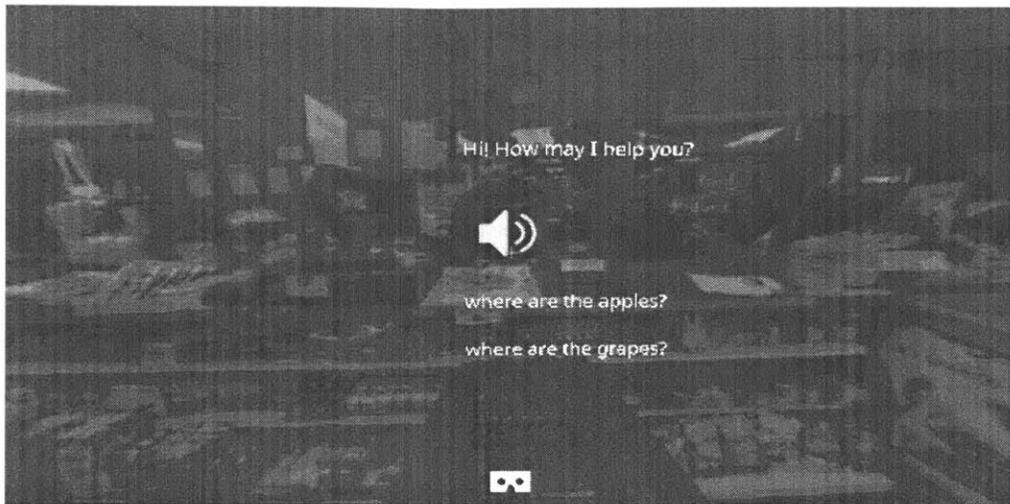
Figure 7 Student's view while participating in a dialog

3.4.1 Goal-oriented Dialogues

It is important for the dialogue to have some motive. To add motive to the dialogue making it more realistic, it can be arranged so that certain photospheres or objects only become accessible after the conversation with the virtual characters. This is similar to real-life situations where you are unable to find a location or object until you ask someone for directions.

Example 1: Tunnel to the Garden appears after asking the concierge :

virtual characters: Hi, how may I help you?

User: Where is the garden?

virtual characters: The garden is next to the entrance (tunnel appears)

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<u>Example 2: Banana object appears after asking a employee at a supermarket:</u>

virtual characters: Hi, how may I help you?

User: Where are the bananas?

virtual characters: The bananas are in aisle 2 (banana appears)

Teachers can create tasks for students such as "pick an apple from the garden" for example 1, or "purchase a banana at the grocery store". In both scenarios, the student is forced to engage in the goal-oriented dialogue to complete the task.

3.5 Annotations feature

The *TagAlong RolePlay* platform allows teachers to add annotations to the scene. When a user is looking in the region that is annotated, the text appears above it. Furthermore, when the student clicks in the annotated area, the annotation is heard using the phone's built-in text-to-speech feature. This way a user can 1) see the object, 2) hear the correct pronunciation of the object, and 3) see how the object is spelled simultaneously. The teacher can add the annotations to the scene either beforehand in the *SceneCreation* authoring tool, or in real-time.

Allowing the teacher to add annotations beforehand, spares the teacher work during the application so that the teacher can spend more time focusing on making sure the users are engaged. However, allowing the teacher to add annotations in real-time is also beneficial since if a student is curious or unsure about what a certain object in a scene is, the student can get the teacher to annotate it on the spot. Furthermore, if one student is curious about a certain object, chances are many of his peers are as well.

Figure 8 An annotation in the virtual environment

3.6 Assigning Tasks (feature)

The *TagAlong RolePlay platform* incorporates task-based learning by allowing teachers to assign tasks for student. Similar to annotations, these can be done in real-time or done beforehand using the *SceneCreator* authoring tool. Furthermore, they can be

personalized even when in a multi-player scenario. For example, in a grocery environment, you can ask one student to "retrieve the banana" and another student to "retrieve the grapes".

When the task is assigned, a text appears on the top right of the student's view. In addition, the text-to-speech feature will read out the student's task. Since the text is attached to the camera object in ThreeJS, the text follows the student and is visible to him at all times.

Figure 9 The student's view when a task is assigned

3.7 Authoring Tool

Teachers can create virtual environments, add annotations, add objects, construct tasks and script dialogs using the user-friendly *SceneCreation* authoring tool. This allows teachers to create personalized virtual environments for students based on their interests needs and level of fluency.
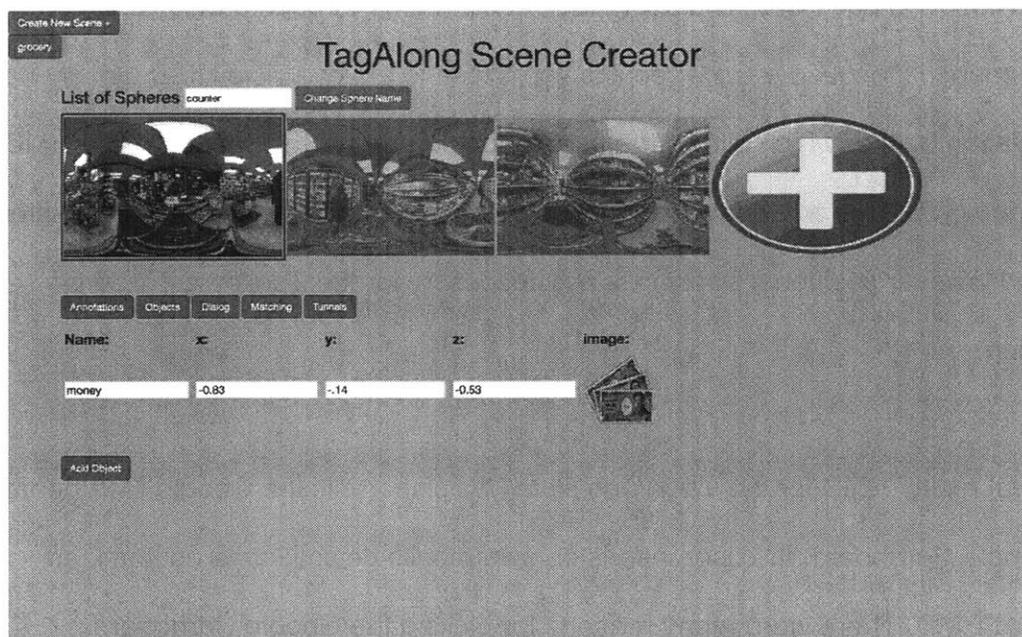
Figure 10 The GUI of the SceneCreation authoring tool

Chapter 4: Technical Details and Implementation

4.1 Virtual Reality

4.1.1. Head Mounted Display

Virtual Reality works by wearing a head mounted display (HMD). The HMD displays a separate image in each eye. The users look at the image through a biconvex lens. This way the image is focused even when it is very close to the eye. The HMD usually has an orientation tracker which allows the user to look around in the space. Some HMD such as the HTC Vive or Google Tango also have cameras installed to allow positional tracking. However positional tracking is not necessary for the *TagAlong RolePlay* application.

The virtual reality HMD for the *TagAlong RolePlay* platform is the Google Cardboard. With Google Cardboard, the user inserts its own mobile device into a customized cardboard HMD. There were many reasons for picking the Google Cardboard.

1) Economical

Firstly, the Google Cardboard is highly economical. Costing only approximately ten dollars compared to hundreds of dollars for an Oculus Rift or $100 for the GearVR, it will

be affordable for any student. Furthermore, in a classroom setting with dozens of students, it will be much for reasonable.

2) Robust

Unlike the GearVR, which is only compatible with a few of the top-end Samsung phones such as the Note 5 or the Galaxy S6 which cost over $500, the Google Cardboard works with just about any smartphone from the last five years.

Choosing amongst the Google Cardboard headsets:

Even amongst the Google Cardboard headsets, there are several variations, varying in material, functionality and price. These are the four I found to be the most beneficial

Easy-View:

The Easy View is by far the most comfortable unbreakable headset. It is made fully of plastic. However other than its reliability it is the most expensive and doesn't have the features such as IPD or eye sight correction.

Knox Viewer 2.0:

The Knox Viewer is the original cardboard headset. It does not have any strong advantages and for that reason I do not recommend this headset.

Unofficial Cardboard:

The *TagAlong RolePlay* platform is an extremely effective tool for kids since they are very easily engaged by the technology. Since kids have smaller faces they tend to have much smaller IPD. The solution is using the "Unofficial Cardboard" that has adjustable lenses to suit the fit anyone eyes regardless of their IPDs. This headset is ideal for children. The headset is also economical at $14 which is ideal for scaling in a classroom. Thirdly the headset is made so that kids can draw on the shell and make it their own.

Powis Viewer:

Most standard Cardboard headsets have a distance of 45mm (the focal length of the lenses) between the cardboard lenses and the smartphone screen. However, for users without perfect eyesight, this can cause the virtual environment to appear blurry. Although users can still experience the VR with glasses or contact lenses, using the headset with glasses is often uncomfortable and not everyone would wear contacts. The benefit of the Powis Viewer is that the depth of the lenses of the Powis viewer can be adjusted. This way users without 20/20 eyesight can still experience a clear VR environment without glasses or contacts.

4.1.2 Head Tracking

For virtual reality to work, what the user sees on the head mounted display (in this case the smartphone), must change as he or she turns his or hear head to look around. To accomplish this task, HTML5's Device Orientation API is used which reads the data from the phone's built-in accelerometer and gyroscope to calculate the phone's orientation. (W3C, 2011).
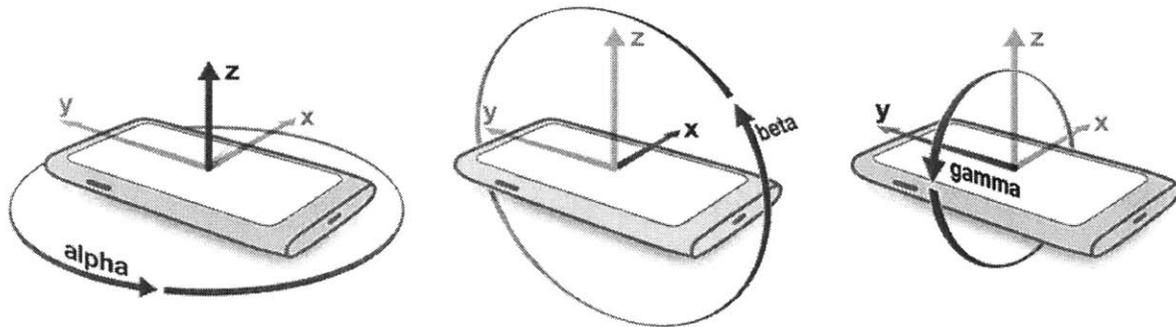
Figure 11 Device Orientation Axis

4.1.3 Photospheres

A *TagAlong RolePlay* virtual environment consist of scenes. Each scene is a photosphere. A photosphere is a 360-degree spherical photo. 360-degree spherical photos can be taken from spherical cameras such as the Ricoh Theta S or the LG 360 Gear. These cameras are no larger than a smartphone, in the range of $200-$400, are extremely user-friendly, and require no technical background to operate.

Figure 12 A 360-degree spherical image in 2D

4.1.4 Tunnels

Since *TagAlong RolePlay* does not incorporate position tracking, the *TagAlong RolePlay* uses tunnels, a visible button in the virtual environment, to allow users to move from one photosphere to another. A tunnel connects one photosphere to another. Users and Teachers can hover on the tunnel to see where it leads (shown in figure 13), and click to on it to hear the pronunciation of the destination. To move, to the destination, the students long press the tunnel, and teachers press the space bar.

Figure 13 Tunnels in the virtual environment: not hovered (left) vs hovered (right)

The default tunnel icon is a door as shown in the left picture of figure 13. However, this can be altered by the teacher in *SceneCreation*.

4.2 Teacher User Interface

4.2.1 Starting the Application for Teachers

The application on the teacher side is opened by going to the URL *https://TagAlong RolePlay.media.mit.edu/roleplay/tabletroleplay.html*. To start the application, the teacher must type in the name he would like to call the room, and pick out a scene from a dropdown menu. The teacher can also choose a private scene that he created in the *SceneCreation* by logging in with a username and password. Although the rooms are public by default, the teacher can also make the room private, forcing to students to type in the password before being able to join the app. Once this is done the teacher presses the start button.

4.2.2 View

Once the teacher starts the scene, teacher is placed in the VR environment. If the teacher is using a tablet, the user can move around using the tablet's device orientation feature similar to the phone. If the teacher is using a computer, the user can move in the virtual space using the arrows keys on the keyboard.
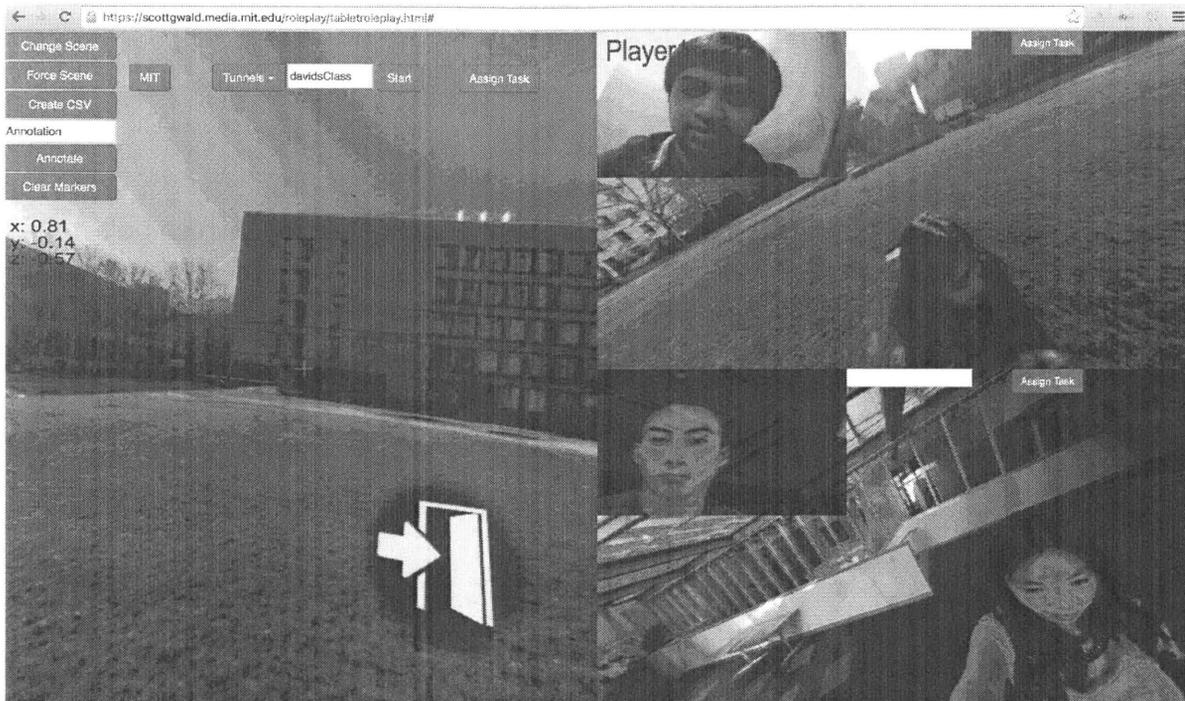
Figure 14 Teacher Interface

Teacher View

The left side of Teacher's screen renders the teacher's view of the VR environment.

Student View

When students log in and start the apps the user's name and picture appears on the teacher's view and students view of the Virtual environment is rendered on the right side of the tablet screen. As more student's join, the teacher's view dynamically changes and allowing more renderings of user's views to fit on the screen.

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4.2.3 Teacher Button Features

The teacher has several buttons that they can press during the sessions which help guide the student's learning experience.

Force Scene: The force scene button moves all the students into the sphere that the teacher is currently in. This is a way of gathering the entire class with a click of a button .

Clear Markers: Although the markers fade over time on their own, occasionally too many markers are placed in the scene affecting the learning experience. Teachers can delete all the markers in the scene with this button.

Assign Tasks: To take advantage of task-based learning, TagAlong RolePlay has the feature to add tasks. Teachers can fill out the input and press the button and the task will be sent to the student.

Annotations: Teachers can add annotations into the scene in real-time.

4.3 Student Login Interface

When students enter the URL and start the application they are sent to the user login page. The login user page is a simple sleek design that is extremely user-friendly. The user login page consists of several buttons overlaid on a 360-degree background. The buttons are overlaid on a canvas element in HTML, where as the background is done in ThreeJS. The four buttons in the login page are:

1) Room dropdown menu

Users can see the various rooms hosted by teachers in a dropdown fashion and pick the one their teachers are running. Teachers can make the rooms password protected (read Security section), where in that case the student will need to type in the password to join.

2) Name:

Users can enter their name, to help others recognize who they are. If this part is left blank, the student is given a default name "Student X", where X is a unique number, in the order that they log into the application. For example, the fifth student to log in, would have the default name "Student 5", if he or she chooses to not input their own name.

3) Profile picture:

When users click the profile button, the front-facing camera takes into effect. Users can then take a picture of themselves for the teacher and other users to recognize who they

are during the application. The image is captured using HTML5's '

Navigator.getUserMedia API.

4) Continue to application:

Users click this button to continue with the application. The user doesn't need to fill out

his name or take a picture to start the application. In that case the user will be shown to

the teacher and other users with a default name and avatar.
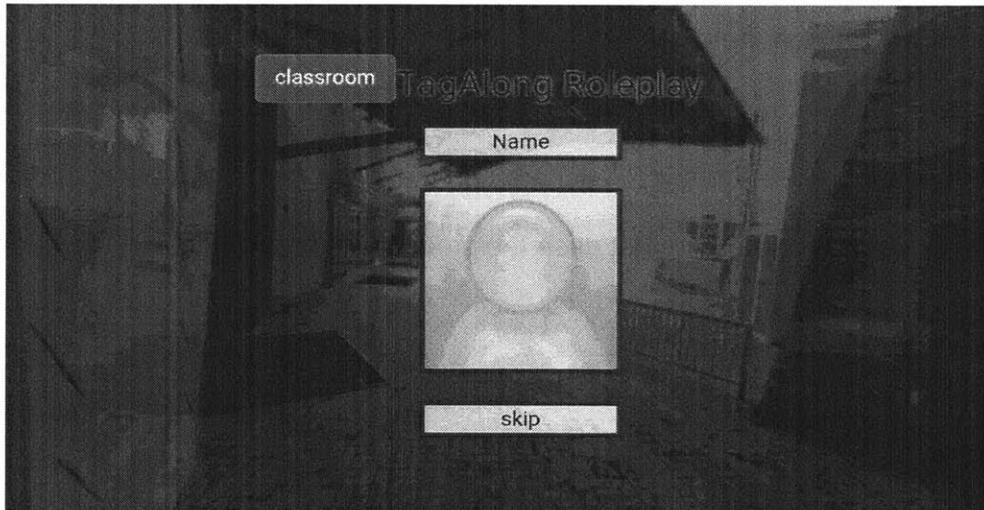
Figure 15 Student User login Interface

4.4 Trigger Button Functionality

For students, to interact with the virtual environment, he or she can click the trigger

button on the Google Cardboard. The trigger button, translates to a touch on the

smartphone using a conductive strip that connects the trigger button to the contact point with the smartphone as shown below.
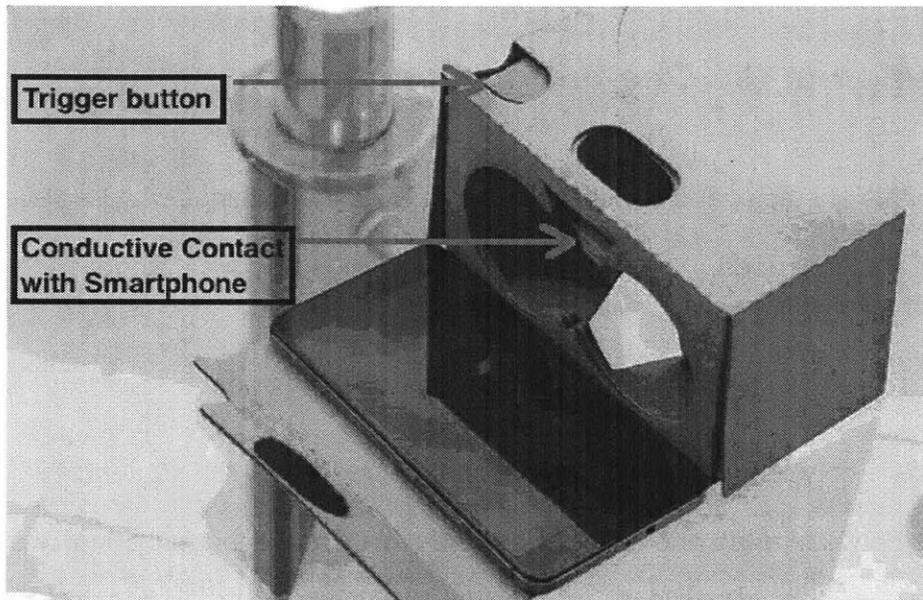
Figure 16 Mechanics of the Google Cardboard trigger button

4.4.1 Combating the One-button Conundrum

One of the obstacles in creating a platform with so many features was that there only exists one trigger button on the Google Cardboard headsets. One of the possibilities to fix this problem was to have users hold a hand controller. However, the problem with this solution is that it adds another dimension of difficulty for the user. The students would have to purchase controllers and configure it to work with the smartphone that they are using. Another solution was to alter the google Cardboard headsets, and add

more buttons. However, this also goes against the idea of *TagAlong RolePlay* being an extremely easy to use platform with very little barrier of entry.

4.4.2 Solution to the One-button Conundrum

To overcome this obstacle, and to allows students to do many things with just one input button, two tricks were used.

Long press vs tap:

Although there is only one trigger button that can be pressed by the student, by differentiating between a tap and a long press we can increase the functionality of the button by a factor of two.

Location-specific Functionality:

Another method that was done to increase the number of functions the student can do was to call different functions based on where the user clicked.

The table below illustrates the different actions the user can do depending on the location and how the user pressed the trigger button.

Table of Location specific button functionality

	Tunnel	Object	Annotation	Matching	Nothing
Long Press	switch scenes	Moves object	slow pronunciation		
Tap	pronunciation	pronunciation	pronunciation	Instructions pronounced	Place marker

Figure 17 Different functions based on where and how you click

4.4.3 Making the Long Press User-Friendly

Although it is intuitive to users what counts as a tap, a long press is not as obvious. It is important for users to know how long they need to press.

Spinners:

To address to student how long to press, a loading spinner appears around the tunnel and dialog objects when they are pressed. To create the loading spinner, I used a gif animator library. (stemkoski, 2013) The gif animator takes a series of images below and displays them frame by frame as an animation.

Figure 18 The loading spinner image that appears as a gif with the texture animator

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```
/////////// Texture Animator code //////////////////////////////////////////////////////////////////
var spinnerTexture =  new THREE.ImageUtils.loadTexture("./media/" + 'loadingspinner.png');
spinMaterial = new THREE.MeshBasicMaterial({map: spinnerTexture});
spinGeometry = new THREE.CircleGeometry(.45,16);
var spinner = new THREE.Mesh( spingGeometry, spinMaterial );

var loadingSpinner = new TextureAnimator(tex,10,1,10,150);


loadingSpinner.update(1000*delta)
```

Figure 19 Code Snippet of Texture Animator

Dynamic Opaqueness:

When a long press is actualized on a tunnel, the user moves scenes. When a dialog
icon is long pressed, a dialog starts. Although, for features such as tunnels and dialogs
it is evident when the long press successfully starts a function, it is not evident when
attempting to move objects. To address to the student that object is now in a moving
state, the opaqueness of the object is changed when long pressed in the moving state
until it is let go.

Figure 20 An object in a moving state(left) vs an object not in a moving state (right)

4.5 TagAlong RolePlay: A Web Browser Application

The *TagAlong RolePlay* platform works solely on the browser for both the teacher and the students. There are many benefits of having *TagAlong RolePlay* be a web-browser application compared to a desktop application.

1) **No installation**: The benefit of having everything on the browser is it doesn't not require any sort of installation. This also means the application will not take any memory on the device.

2) **Ease of use**: Using the platform is as easy as typing the URL into the browser.

3) **Low Barrier of entry**: Due to reasons 1) and 2) stated above, in addition to the fact that the application requires nothing but a smartphone and an optional google cardboard, it will be much easier to gain new users than an application that requires installation. This accessibility makes it easier for students to use the platform frequently and consistently which is crucial for language acquisition.

4) **Compatibility**: Most web based applications are far more compatible across platforms than traditional installed software. So whether you use a Windows, Linux or Mac OS or are using a tablet, phone or desktop computer, you can still run the web application. (Green, 2012) .

5) **Responsive Design**: Web browsers such as Google Chrome have incredible responsive design, and provide a customized optimal viewing and interaction experience for each device depending on their resolution, size, and more. So whether you use a phone, tablet or PC, the web application works well.

6) **Maintenance**: when updates are made to the TagAlong RolePlay platform, there is nothing that needs to be updated on the teacher or user device since there is nothing installed. This is convenient for both the users and the administrator.

Hosting:

The platform is hosted on the MIT servers. The teacher side URL is https://TagAlong RolePlay.media.mit.edu/roleplay/teacher.html and the student side URL is https://TagAlong RolePlay.media.mit.edu/roleplay/student.html.

4.6 Creating the Virtual Environment using ThreeJS

To create the virtual environments, (Three.js, 2010) was used. ThreeJS is a JavaScript library used to render 3D graphics on a web-browser using WebGL. There are several benefits of using Three JS over other rendering libraries such as Unity and Unreal Engine.

1) **Compatibility:**

ThreeJS is compatible with any web browser than can run WebGL, which is essentially all browsers. Other engines such as Unity do not work on all mobile browsers.

2) Performance:

Since ThreeJS is a framework and is much more low-level then the engines such as Unity, it will have much better performance.

3) **Memory**:

Unity requires a wrapper that is approximately 200MB, while ThreeJS is extremely light-weight (less than 1MB).

```
///////// Three JS code ///////////////////////////////////////////////////////////////////////////
scene = new THREE.Scene()
camera = new THREE.PerspectiveCamera(VFOV, aspectRatio, 0.1, 1000);

var geometry = new THREE.BoxGeometry( .5, .5, .005 );
var material = new THREE.MeshBasicMaterial({map: THREE.ImageUtils.loadTexture('image.png')});
var object = new THREE.Mesh( geometry, material );

object.position(1,0,0);

scene.add(camera);
scene.add(object);

renderer = new THREE.WebGLRenderer();

render();

function render(){
    renderer.render(scene,camera);
    requestAnimationFrame(render);
}
///////////////////////////////////////////////////////////////////////////////////////////////////
```

Figure 21 Code snippet of ThreeJS

Anything visible in the virtual environment, ranging from texts, objects, photosphere, tunnels, tasks, to annotations are created and rendered with ThreeJS.

Visible Objects

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One feature of the *TagAlong RolePlay* platform are visible objects in the virtual environment. This uses a ThreeJS mesh of an image. Visible Objects are placed in front of the photospheres. These objects can then be moved in the virtual environment by users. Changing the opacity, size, and position of objects can easily be altered in ThreeJS.

4.7 Multi-User functionality using PeerJS

PeerJS (Bu & Zhang, 2014) was used to allow users and teachers to communicate to one another. PeerJS is a library that simplifies the use of WebRTC (Google, 2015) with an elegant API. WebRTC is a technology that enables real-time communication between web browser with low latency. With PeerJS, identifying peers is very simple. Every peer is identified using nothing but an ID. PeerJS also helps ensure that the Data Channels being used are reliable.

```
Tablet receive call

peer = new Peer('tablet'+roomname, {host: 'tagalong.media.mit.edu', port: 9001, path: '/'});
peer.on('connection', function(conn) { // receive call from student
    conn.on('data', function(data){ // to receive data from student
        handleData(data)
    }
}

conn.send(['data']); //to send data to student


Student make call

peer = new Peer(roomname + newID , {host: 'tagalong.media.mit.edu' , port: 9001, path:'/'});

conn = peer.connect('tablet' + roomname);
  conn.on('open', function(){ //call went through to teacher
        conn.on('data', function(data){ //to receive data from teacher
      handleData(data);
    });
  });

conn.send(["waiting"]); //to send data to teacher
```

Figure 22 Code snippet of PeerJS

Peer-to-peer Data Connections:

Each student's smartphone has a data connection with the teacher's device. Students

communicate with each other by sending data to the teacher who then relays the data

to the other students.
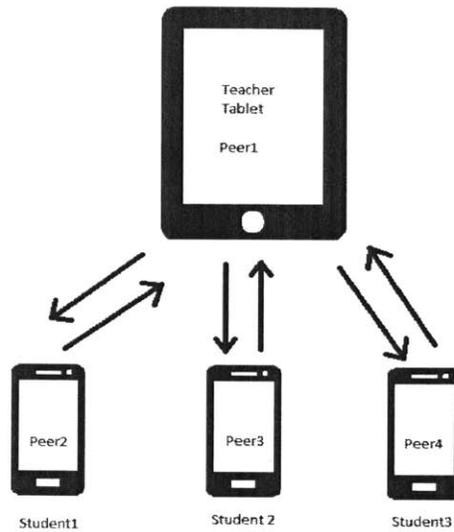
Figure 23 Data Connection Channels of TagAlong RolePlay using PeerJS

Multiple Sessions:

In order to allow multiple sessions to run at once, each teacher's peer id is uniquely created, based on what they name their session. For example, if the teacher calls his class session "English 101", the peer id of the teacher tablet is "tabletEnglish 101". *TagAlong RolePlay* will then have students wanting to join this session to communicate with the peer with this ID. This prevents students from getting connected to the wrong sessions, and the teachers from getting connected to the wrong students.
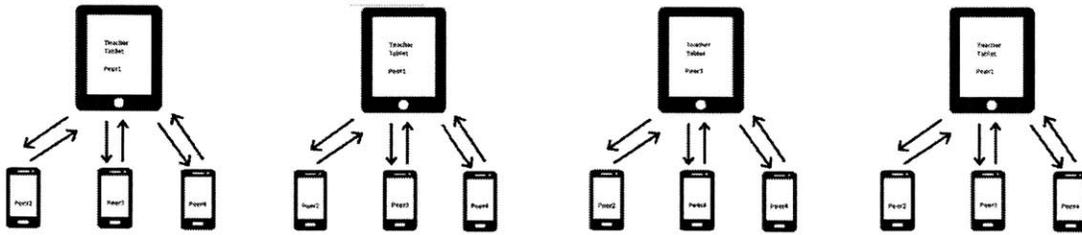
Figure 24 Data Connection Channels with multiple sessions

4.8 Marker Animation using TweenJS

Since a marker appearing randomly in the scene would be hard to notice, the markers fly from the other end of the photosphere to their final destination, making them easily visible. To create this fly-by animation, an animation library called TweenJS (short for in-betweening was used). TweenJS (gskinner, 2015) allows for simple, fast and easy animations and is highly compatible with ThreeJS. Using TweenJS, markers are also designed to fade with time as they become irrelevant.

```
// TweenJS Marker code ////////////////////////////////////////////////////////////////////////////////////////

    var tween1 = new TWEEN.Tween({scale: 7, x: -posVector.x, y: -posVector.y, z: -posVector.z})
        .to({scale: .05 , x: posVector.x, y: posVector.y, z: posVector.z}, 250)
        .easing(TWEEN.Easing.Quadratic.Out)
        .onUpdate(function(){
            torus.scale.set(this.scale, this.scale, this.scale);
            torus.position.x = this.x;
            torus.position.y = this.y;
            torus.position.z = this.z;

        })
        .onComplete(function(){
            torus.lookAt(new THREE.Vector3(0,0,0));
            scene.children[otherscene-1].children[2].add( torus );
        });
    tween1.start(); // start marker animation


    TWEEN.update(); // to animate marker
////////////////////////////////////////////////////////////////////////////////////////
```

Figure 25 Code snippet of TweenJS

4. 9 Text-to-Speech Algorithm

There are many occasions during the *TagAlong RolePlay* sessions such as when an
annotation is clicked or during a dialogue where the phone needs to produce speech.
To convert the text-to-speech in the *TagAlong RolePlay* platform, a HTML5 based Text-
to-Speech Library called ResponsiveVoiceJS is used (ResponsiveVoice™, 2016).
ResponsiveVoiceJS supports 51 languages over 168 voices, and only takes up 14kB of
space. It also works consistently with all devices ranging from phones tablets to desktop
computers.

Code:

Here is a simple example to get the phone to say "hello world".

```
responsiveVoice.speak("hello world", "UK English Male");
```

In the example below, the speech is slowed down. This is used in the *TagAlong RolePlay* platform when the turtle icon is clicked on an object or annotation.

```
responsiveVoice.speak("hello world", "UK English Male", {rate: 0.5});
```

4.10 Speech Recognition

In addition to Text-to-Speech, *TagAlong RolePlay* also utilizes, speech recognition to run features activated by speech. Speech Recognition was done by HTML5's built-in Web Speech API (W3C, 2012).

Applications:

There are three primary applications where Speech Recognition is used in the *TagAlong RolePlay* platform.

1) Teachers adding annotations by speech

The first example is giving the teacher ability to add annotations in real-time without typing. For example, to add an annotation "table" in the VR environment, the teacher

can simply point the view at the space he wants the annotations and say "create table". The platform will then recognize the teacher and produce the annotation.

Although, annotations can also be added by typing, some teachers may prefer this method. This is especially true for users using a tablet with no keyboard.

2) Student's dialogue validation via Speech Recognition

To ensure that the speaker is actually pronouncing the words correctly, *TagAlong RolePlay* uses Speech Recognition to listen to the user. When the student recites one of the given responses, the dialogue will continue. Students are also given the option to click the response they would like use. It will be up to the teacher to decide how he wants his student's to interact with the dialogues.

3) Student log in

Input boxes that require typing is highly user-unfriendly. As a goal to eliminate the need for typing completely on the student side, students can input their name in the log-in process using speech Recognition. When the student says "My name is _____", the Name input box will be filled out. This is also good practice for the student to practice the phrase each time he logs in to the applications as opposed to just typing his name which there is no learning to really be done.

The large downside of speech recognition however (i.e. the reason why these applications are primarily done using other methods instead of speech recognition), is due to the fact that it only works when the user is in a quiet and secluded area. This will not work in classrooms as the speech recognition will pick up more than just the user's speech.

4.11: Authoring Tool

'We don't deserve students' attention, we earn it!' (Zhu, 2015)

4.11.1. SceneCreation

SceneCreation is an authoring tool to allows teachers to effortlessly create and edit virtual environments. *SceneCreation* is also done all on the browser and can be accessed at the URL, *https://www.TagAlong RolePlay.media.mit.edu/roleplay/scenecreation.html*

SceneCreation uses AJAX to communicate with the server to create directories, add images for photospheres and objects, in addition to a CSV file, which provides all the details of such as the location and names of the objects and annotations, the tasks, the content of the dialogues. The server-side application is written in NodeJS (Node.js Foundation, 2016), a JavaScript-based platform used for creating server-side web applications.

4.11.2 CSV

TagAlong RolePlay creates the virtual environments, using the CSV files created by teachers via the *SceneCreation*. However, tech-savvy teachers may also choose to author environments directly using the CSV.
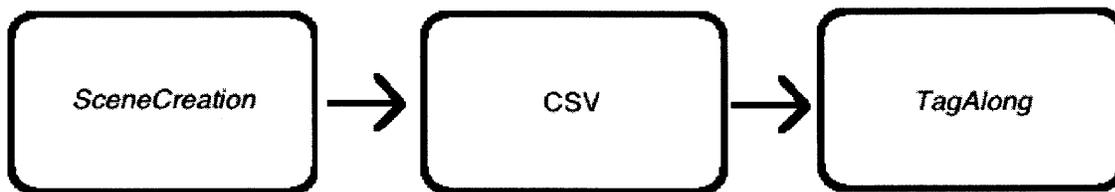
Figure 26 The flow of content in the TagAlong RolePlay platform

4.12 Matching Tasks

4.12.1 Matching Objects

Similar to visible objects discussed in 4.5, a matching object is a visible mesh of an image in the virtual environment created by ThreeJS. The Matching objects allow teachers to create scenarios where the students need to find an object and drag it over to the matching pair. An example of this is a zoo scenario with many animals (visible objects) and cages (matching objects). The student's task is to place the correct animals in their corresponding cages.

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TagAlong RolePlay continuously checks the distance between the matching object and its object pair. When the distance is below a certain threshold, it knows the object was correctly placed.

4.12.2 Matching Instructions

For the student to know which object should be placed on the matching object, the student must be given the instructions. Student's can either hover over the matching object to visibly see the instruction in text, or can click the matching object to hear the audio of the instruction.

Once the correct object is placed on the matching pair, the user will be notified that he or she successfully did so with a short audio that is played and a text that will appear in front of the object. Although the default text for a correct matched pair is "Matched", the text can be programmed by the teacher to whatever is appropriate. An example is a task where the student is required to help a dog owner find his dog. In this scenario, the dog owner is the matching object and the dog is the visible object. In this specific case, the text on success would be more appropriate for it to say "Thank you!" rather than "Matched!".

Figure 27 Only when the correct animal is placed do you get a match (mismatch on left vs correct match on right)

Chapter 5: *TagAlong RolePlay* Outside of Language Learning

TagAlong RolePlay is a very robust platform, and it would be a shame to limit it to just language learning. Other applications of the platform can be for teaching STEM and for giving virtual tours.

5.1 Virtual *TagAlong RolePlay* Tours

For this experiment an MIT tour with 11 spheres was created. In each sphere the user can look around in the environment and read interesting facts and annotations that have been placed. These spheres and annotations can be thought of to be equivalent to when the tour guide stops the group at a notable site and speaks to the group some of the interesting details and history of the site.

Benefits for tour guide:	Benefits for the customers:
Only have to make it once Don't have to be present	Free Go at own pace Interactive Can be done at home or anywhere Physically-disabled can participate

5. 2 *TagAlong RolePlay* for STEM and Social Studies Education

As 360 spherical cameras become more and more accessible and perhaps even built into smartphones, the amount of 360 spherical images available online will continue to grow. If Images are available online, teachers can easily create virtual environments of places that are of interest for what they would like to teach.

For example, teachers will be able to teach students about outer space such as the solar system if they can obtain photospheres (either real or simulated) for them. This would be a lot more engaging for the students than just reading the material in a textbook.

Figure 28 A screenshot of a Chemistry lesson in TagAlong RolePlay

Another example would be teaching marine biology. Teaching students the rare organisms living deep in the ocean would be as easy as finding a simple 360 spherical image of the and filling the scene with images of these rare organisms.

The last example, would be chemistry. By allowing different chemical compounds to be objects, students can have tasks to mix compounds together to create new ones. This semi-hands on way of learning could be helpful in cases where performing the actual experiments could be too expensive or inaccessible due to safety reasons.

$$2H_2O_2 + MnO_2 \rightarrow 2H_2O + O_2 + MnO_2$$
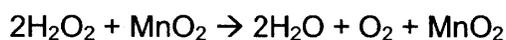
In figure 24, students place the catalyst manganese dioxide (MnO_2) on the hydrogen peroxide (H_2O_2) which starts a reaction splitting hydrogen peroxide in to water and oxygen gas.

Chapter 6: Conclusion and Future Work

6.1 Summary

A realistic, immersive, cost effective virtual environment language learning platform was developed and described in this thesis. The platform attempts to integrate all of the different types of language learning such as peer learning, task-based learning, tandem learning, conversational-based learning and personalized learning.

TagAlong RolePlay was made specifically to have a low barrier of entry that is accessible to almost anyone. The platform is web-based, allowing anyone to access it without installation.

For, the student, the platform uses smartphones as the display of the virtual environment. Students have the option of using a Google Cardboard to experience the virtual environment in Virtual Reality, or can use the monoscopic mode. The platform is multiuser so that students can interact with their peers and perform tasks together.

The teachers use either a tablet or a computer. Teachers can see their students' views and can also interact with them with markers. Teachers are given the ability to control the student's learning experience, by assigning tasks, adding annotations in real-time and moving the students from scene to scene. Teacher are also able to create the

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virtual environments, using either the *SceneCreation* authoring tool or directly changing the CSV.

Other applications of *TagAlong RolePlay* outside of language learning were discussed in Chapter 5. A virtual tour of MIT was created as an example. Possibilities of using *TagAlong RolePlay* for other forms of education were also discussed. An example for teaching chemistry was presented.

6.2 Future Work

The summary of the potential future work are as follows:

1) **GearVR Compatibility:** Although Google Cardboard has many benefits as discussed in chapter X, there are also a few benefits to have the application run on GearVR. The two advantages are eyesight correction and better orientation tracking.

2) **Evaluation and improvement of current model:** The platform can be tested further to find area of improvement. These potential areas for improvements can then be carried out.

3) **Animated Dialogs and Objects:** Dialogs with virtual characters can include videos, to appear more realistic. Furthermore, objects and photospheres can be

animated. This may be helpful to learn words such as "jumping" which is much easier to show with an animation rather than a still image.

4) **Progress tracker:** There does not currently exist some a feature that tracks your participation, tells you, or lets you know how well you are doing.

5) **Full courses:** Currently there exists approximately ten scenarios, but there does not exist an entire language course one can take. Creating an entire course for a few languages could be a next step.

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